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TWO RAPID METHODS FOR ESTIMATING FINENESS AND CROSS-SECTIONAL VARIABILITY OF WOOL

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INTRODUCTION

In an earlier publication (*3*)[1] an improved technique was described for projecting cross sections of fibers on sensitized paper and for determining fiber fineness and variability from these photomicrographs. This procedure was made possible through the use of a device for making cross sections about one sixty-fourth of an inch in thickness, which are easily projected through a microscope in the case of wool or mohair that is undyed and not heavily pigmented. Later, the application of this method was broadened to include all kinds of fibers, dyed or undyed, through the invention of a device for making thin cross sections of fibers rapidly (*4*). Von Bergen (*8*) had previously utilized the projected images of the fibers to show their fineness and variability. With that method, there is difficulty in bringing a number of fibers into sharp focus at one time, and, therefore, it is undesirable for producing photographic records. Although the method is superior for getting a picture of the variation in thickness along the fiber length, it furnishes no information regarding the cross-sectional contour of the fiber. The spinning qualities of a given textile fiber are dependent to a great extent on this cross-sectional shape and are of importance in synthetic fibers as well as in wool.

By the use of the improved technique for photographing cross sections of fibers, about 30 photomicrographs a day, each containing at least 100 fibers, can be obtained by a single operator. On the other hand, only about 6 samples can actually be measured for fineness and variability when 100 fibers of each sample are used. Therefore, the production of cross sections is much faster than their analysis.

Selecting sheep on the merit of their fleeces or culling, from a flock, individual sheep producing undesirable wool, necessitates a quick, reliable method for determining fiber fineness. Eye judging of wool

[1] Numbers in parentheses refer to Literature Cited, p. 15.

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for fineness, although a rapid method, is subject to considerable personal error. Furthermore, the application of wool-fineness measurements in a sheep-breeding program requires that determinations on individual sheep be available for use about 3 months after shearing, when the matings are being planned in the fall. The methods in use for making individual fiber measurements were not sufficiently rapid when large numbers of sheep were involved. Also, in wool-growth studies in which the factor of fineness is to be investigated, accurate and speedy methods for such determinations are desirable.

This circular presents two methods for rapid and accurate determinations of wool variability. These are known as the count and comparator methods. By the use of either one, cross sections may be analyzed quickly. Greatly enlarged cross sections, when compared visually with standard cross sections of measured fineness and variability, may be judged with a reasonably high degree of accuracy. A large number of samples can be studied quickly whether they are from different locations on the sheep or from one of the many steps in the manufacture of wool into cloth.

COUNT METHOD

OBTAINING AVERAGE DIAMETER OF FIBERS

Inasmuch as the cross-sectional picture is a permanent record of the wool fibers, this method was selected for showing the actual variation in wool fibers in an individual fleece. As has been indicated, the individual measurement of fibers is a long and tedious task. A method, called for convenience the count method, developed in the Bureau of Animal Industry, eliminates this objection to the cross-sectional method. In the count method the mean diameter of a given number of fibers is estimated by obtaining the number of fibers in an area of 125 square centimeters of the projected image at a magnification of 500 diameters.

Empirical relationships between fineness of fibers and the number of fibers that can occupy a given area have been shown to exist. It is apparent even to the casual observer that 100 coarse fibers, such as 36's spinning count, will make a thicker bundle than 100 fine fibers, such as 80's spinning count. According to McMurtrie (*6*), Koehler was probably the first investigator to utilize this fact in determining the fineness of wool. Both Küsebauch (*5*) and Hardy (*1*) made use of the principle but without eliminating the time consumed by counting individual fibers. None of these methods showed the variation occurring in the size of the fibers. Later a method for determining fineness, which at the same time showed a cross section of the fibers, was published by Hardy (*3*). In this method the number of fibers occupying a given area is shown by means of a diaphragm placed in the ocular of a microscope. This facilitated the counting of the fibers and also made it possible to observe the variability in both size and shape of a fiber.

Since the publication of Hardy's method (*3*), improvements have been made in the equipment used in projecting the cross sections on sensitized paper (fig. 1), and more careful analyses of the cross sections are possible. However, a mathematical relationship between average diameter and the number of fibers had not been established previously. In order to develop a theoretical relationship between

average diameter and number of fibers in a given area on a sensitized paper, the variables affecting the number must be considered. These variables are as follows: Magnification, fineness of fiber (average diameter), area to be considered, and tightness of the packing of the fibers.

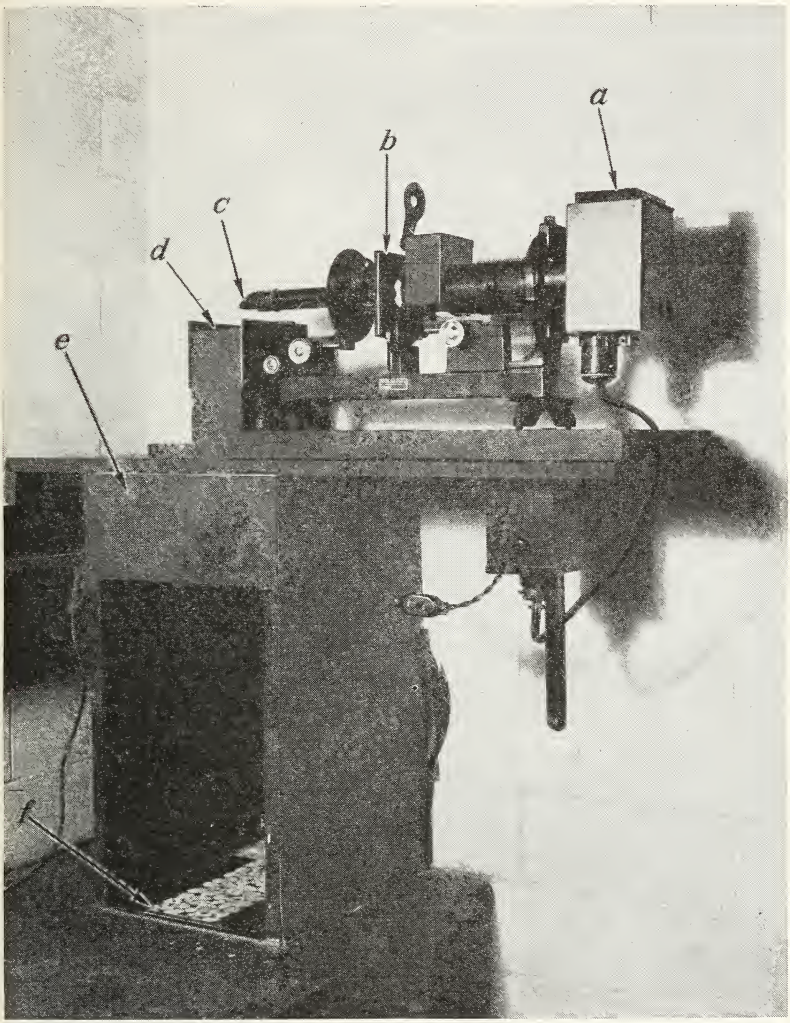

FIGURE 1.—Horizontal type of microprojector showing fibers magnified at 500 diameters: *a*, Lamp and lamp housing furnishing illumination; *b*, stage for holding slide containing cross sections of wool fibers; *c*, prism mounted on ocular to give a horizontal projected image; *d*, filter holder and filter to furnish contrast to imagé; *e*, shielding around screen to eliminate extraneous light; *f*, projected cross sections of fibers.

The magnification of the fibers and the area of the projected image can easily be made constants. The packing of the fibers, however, is more difficult. The degree of packing refers to the number of

fibers contained in a given area of the cross-sectioning device. The fibers must be held firmly enough in the cross-sectioning device so that they can be cut smoothly by a razor blade. The ideal tightness of packing would involve sufficient pressure on each fiber to bring all fibers in contact with adjacent ones without distortion. Fibers so packed may be smoothly cross-sectioned, and from such cross sections the best photomicrographs are obtained. In practice, however, this degree of packing can only be approximated. Three general types of packing actually occur. They may be called for convenience loose, adjacent, and solid (fig. 2). The last two types of packing are expressed by formulas obtained by mathematical analysis.

In adjacent packing the fibers are so compressed in the slot of the device that all of them are brought into contact with one another. The number of fibers so packed may be found by means of the following formula:

$$N=\frac{A}{d^2}$$

in which N=number of fibers; A=50,000 square microns of the slot, an area which when projected at 500 diameters' magnification occupies 125 square centimeters; and d=average diameter of the fiber in microns, 1 micron being equivalent to approximately 0.000039 inch. Therefore, each fiber of average diameter, d, will occupy an area equivalent to the square of the diameter. Table 1 shows the relationship between number of fibers and average diameter of fibers, from the finest to the coarsest, for adjacent packing. From these data a curve showing the relationship between mean diameter in microns and the count of fibers in an area of 125 square centimeters, for the adjacent type of packing, may be plotted (fig. 3).

TABLE 1.—*Relation between the mean diameter and the number of fibers in an area of 125 square centimeters found on the projected image of the cross section at 500 diameters* *

Mean diameter of fiber (microns)	Fibers counted in 125 square centimeters of area packed—			Mean diameter of fiber (microns)	Fibers counted in 125 square centimeters of area packed—			Mean diameter of fiber (microns)	Fibers counted in 125 square centimeters of area packed—		
	Loose	Adjacent	Solid		Loose	Adjacent	Solid		Loose	Adjacent	Solid
	Number	*Number*	*Number*		*Number*	*Number*	*Number*		*Number*	*Number*	*Number*
10	-------	500	637	25	74	80	102	35	36	41	52
15	-------	222	284	28	57	64	81	37	32	37	47
18	-------	154	197	30	48	56	71	39	28	33	42
20	122	125	159	32	42	49	62	40	-------	31	40
22	98	104	132	33	40	46	59	42	-------	28	36

As already stated, the solid type of packing is also capable of mathematical analysis. This type of packing occurs when the slot of the device is completely filled with wool fibers and therefore is subject to a rigorous analysis. Even when the fibers are under sufficient compression to cause this type of packing, the cross-sectional area of the individual fiber is practically unchanged, though its shape is altered. Since measurements are made in terms of diameter, the fibers are considered as circular and therefore the area occupied by a fiber will be that of a circle of diameter, d, despite its

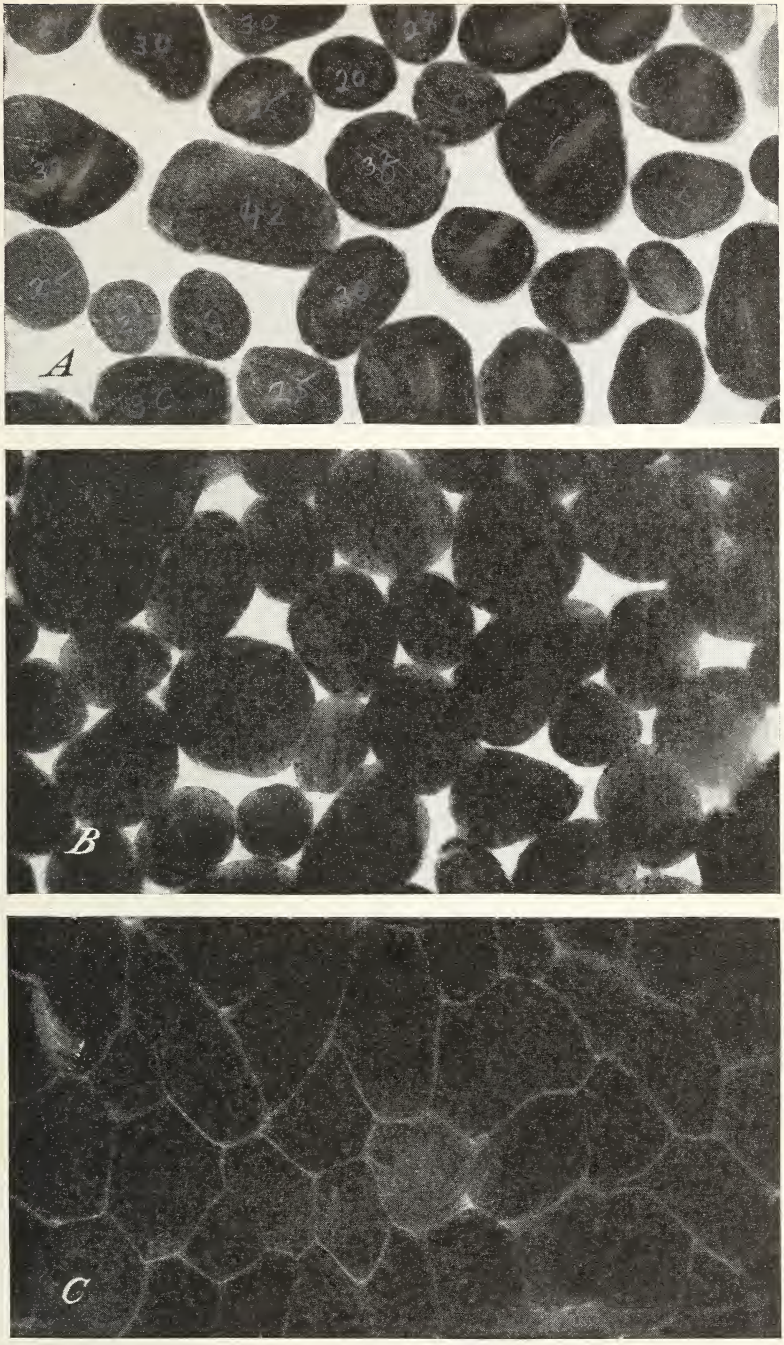

FIGURE 2.—Photomicrographs of cross sections of wool fibers at 500 diameters' magnification, showing three types of packing: *A*, Loose; *B*, adjacent; and *C*, solid (mean diameter, 28.5 microns).

distorted shape. The number of fibers in an area when this type of packing is used may be determined by the following formula:

$$N=\frac{A}{\frac{\pi d^2}{4}}$$

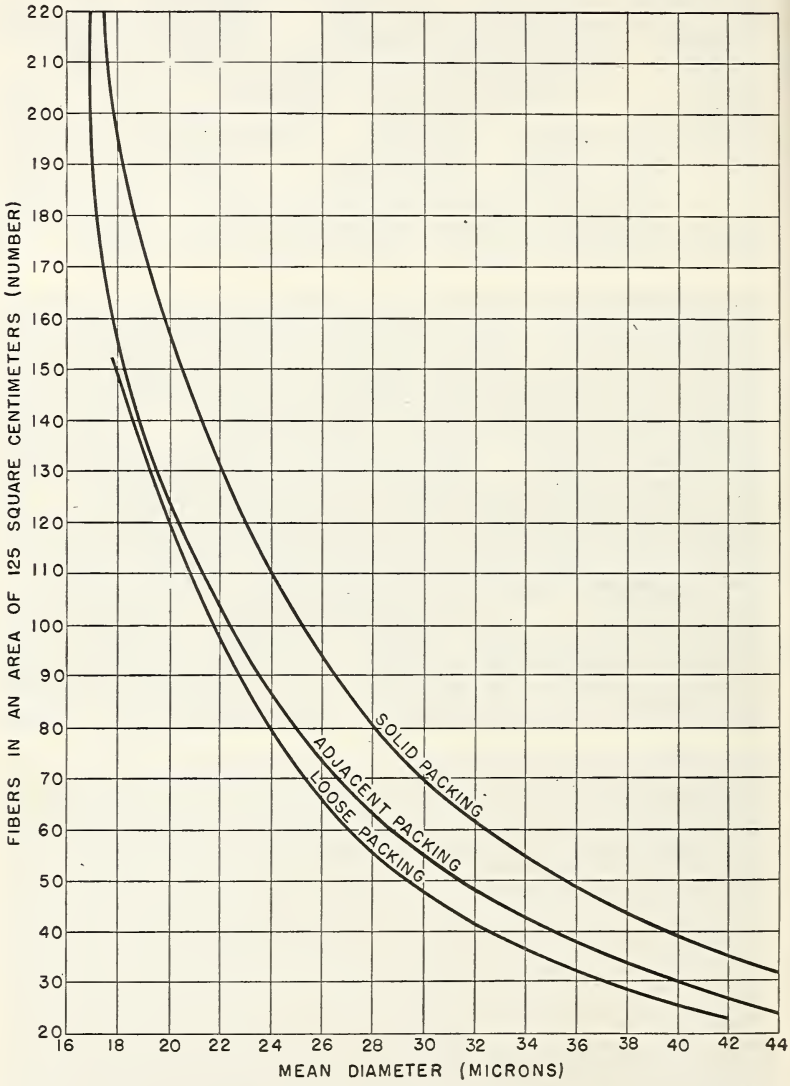

FIGURE 3.—Relation between the mean diameter and the number of fibers in an area of 125 square centimeters, when the indicated types of packing were used.

in which N=number of fibers; A=50,000 square microns of the slot, an area which when projected at 500 diameters' magnification occupies 125 square centimeters; and d=average diameter in microns.

Data on the number of fibers of average diameter in a given area when the solid type of packing was used are given in table 1 and figure 3.

Data for the loose type of packing are also given in table 1 and figure 3. In this type of packing a small space occurs between adjacent fibers, as shown in figure 2, *A*. Although there are many types of spacing, it has not been found practicable to show more than the one. The data given in this circular for loose packing were compiled from a number of cases for which there was evidence from the photomicrographs that the fibers were packed in this manner. In practice, it is advisable to regulate the packing so that one of the three curves shown in figure 3 may be utilized. An examination of the photomicrographs shown in figure 2, illustrating the three types of packing, gives a comparison of the different arrangements of the fibers existing under these conditions.

In all types of packing the fibers may be counted in either of the following ways: (1) All fiber cross sections except those for which it is estimated that more than half of the area is outside the limits of the 125 square-centimeter area are counted and recorded; or (2) all fibers

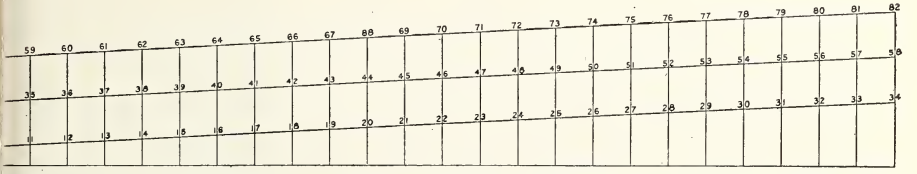

FIGURE 4.—Transparent scale for measuring diameter of wool fibers. (Reads directly in microns for fibers magnified 500 diameters.)

not touching the boundary lines of the rectangular area are counted, and then all the fibers intersected or touched by the boundary lines are counted. This last number is divided by 2 and the result added to the rest of the fibers counted. There is no material difference in the count from the use of either procedure.

By the use of the curves shown in figure 3, the mean diameter of the fibers may be determined after the count in a given area has been obtained. For obtaining the fiber variability, additional diameter measurements must be made. This is easily done by measuring directly with a transparent scale (fig. 4) and obtaining the average diameter in microns for the two largest and two smallest fibers in the cross section. In making these direct measurements on the diameter of wool fibers, it is helpful to have a scale already calibrated to read directly in microns under a magnification of 500 diameters.

In order to determine the diameter of a single wool fiber, two measurements are made over the cross section through the major and minor axes, and the average of these measurements is taken as the diameter.

When cross sections are not photographed on sensitized paper, it is convenient to trace the outline of the two largest and two smallest fibers on a sheet of paper or to measure them directly from the projected image.

It has been estimated that the count method is at least three times as fast as one requiring measurements from photomicrographs of cross sections of individual fibers. In samples of all degrees of fineness of

fibers and types of distribution, deviation of the average diameter obtained in this manner does not exceed by more than ± 0.5 micron the average diameter obtained by measuring 100 fibers of the sample under consideration. Table 4 compares the calculated value and estimated value obtained by the count method for 20 individual samples of wool.

DETERMINING VARIABILITY OF FIBERS

Mathematically, variability is expressed in terms of standard deviation or coefficient of variation, and, therefore, it is desirable to obtain quickly one of these expressions. Since no array of values for the diameters of fibers is possible by the count method, the standard deviation must be deduced from some other procedure. A set of empirical curves (fig. 5), with variables of mean diameter, standard deviation, and coefficient of dispersion (ratio of range in diameter to mean diameter), has been utilized to estimate the standard deviation from data supplied by the count method.

In these curves range is used as a measure of variability. As range is usually expressed, it is subject to so much fluctuation that it cannot be used as a reliable measure of variability. Tippett (7), using the term "average range," gives a table showing the ratio of mean range to the standard deviation for varying populations of normal distributions. For example, when 100 fibers are considered, the ratio is given in Tippett's table as 5.015. Since by the count method it is not possible to get an array, a different means of determining the range was necessary. This was accomplished by the procedure already discussed, in which the average of the two largest fibers and the average of the two smallest fibers are taken, and the difference between these two averages was used to represent the range. If it is assumed that distribution is normal, Tippett's relationships may be used. Since, however, wool fibers are not usually found in normal distribution, the curves plotted from actual data on various wools ranging widely in fineness and variability were more accurate. These curves were plotted with standard deviation as the ordinate and the mean diameter as the abscissa, the locus of all points having the same coefficient of dispersion being found to lie on a straight line. Therefore, it is possible to construct a set of curves having different coefficients of dispersion. The uppermost curve represents the condition of greatest variability and the lowest curve that of greatest uniformity in diameter.

Tippett's table may be plotted in a similar manner by converting the range into coefficients of dispersion. This set of curves (fig. 6) for normal distribution is given for comparison with curves (fig. 5) for actual wool distribution. Figure 5 gives the desired values for standard deviations in the case of wool fibers. The value of mean diameter in microns is found along the horizontal or x axis, and the value of the standard deviation in microns is found along the vertical axis. Table 2 shows a comparison of values of standard deviations obtained through the use of these two sets of curves and the calculated values. The calculated values of standard deviation are obtained from the measurement of 100 separate fibers, it being assumed that 100 measurements give a satisfactory picture of the population of wool fibers. Tippett's formula applies more rigidly to the lower values for standard deviation, but as the variability of wool increases the values obtained in

this manner deviate considerably from the calculated value. The empirical curves (fig. 5) furnish a closer agreement with the calculated values from low to high values of the standard deviation. When small numbers of fibers are considered, these curves are superior. Tippett's

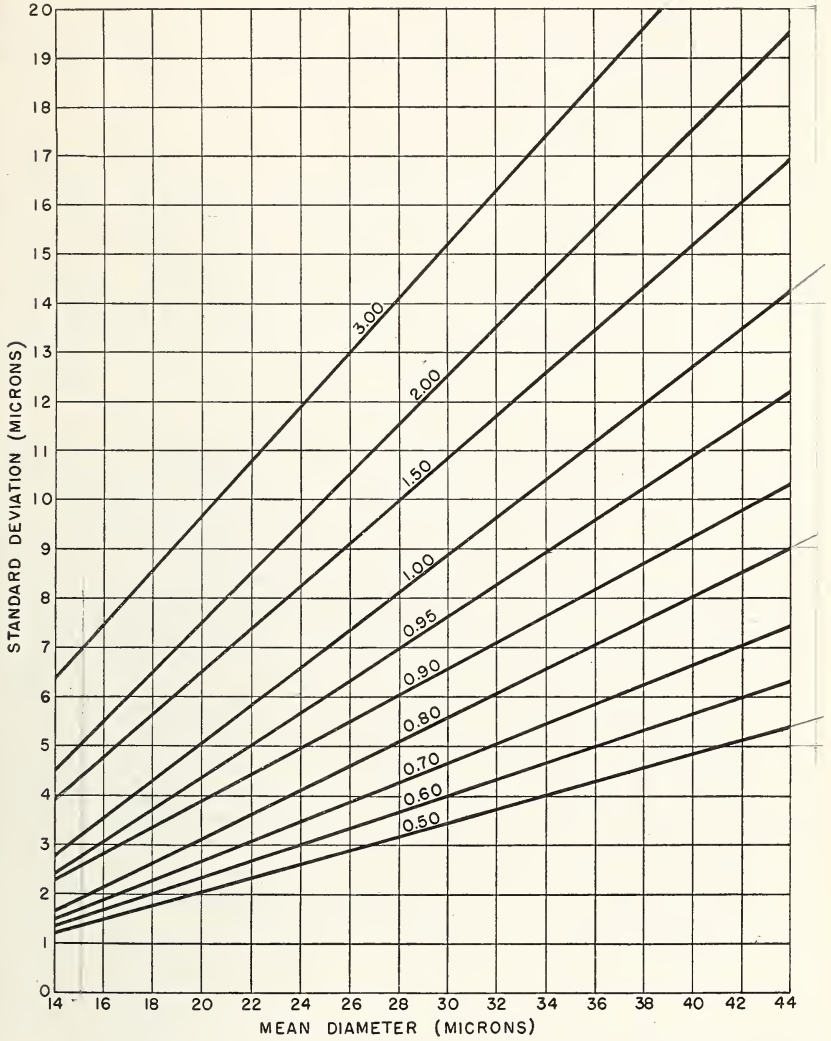

FIGURE 5.—Relationship between mean diameter and standard deviation of wool fibers ranging widely in fineness and variability. Numbers on curves represent coefficients of dispersion $\left(\frac{\text{range in diameter}}{\text{mean diameter}}\right)$.

formula is based on normal distribution which is better realized as the number of measurements in any population is increased.

The use of the curves may be demonstrated by selecting a sample having a mean diameter of 30 microns. This value is located along

the x axis (horizontal axis). From this point the vertical axis is followed upward until it intersects the curve having the coefficient of dispersion 1.0. The point where this line meets the curve gives the value of the standard deviation. The coefficient of variation is then

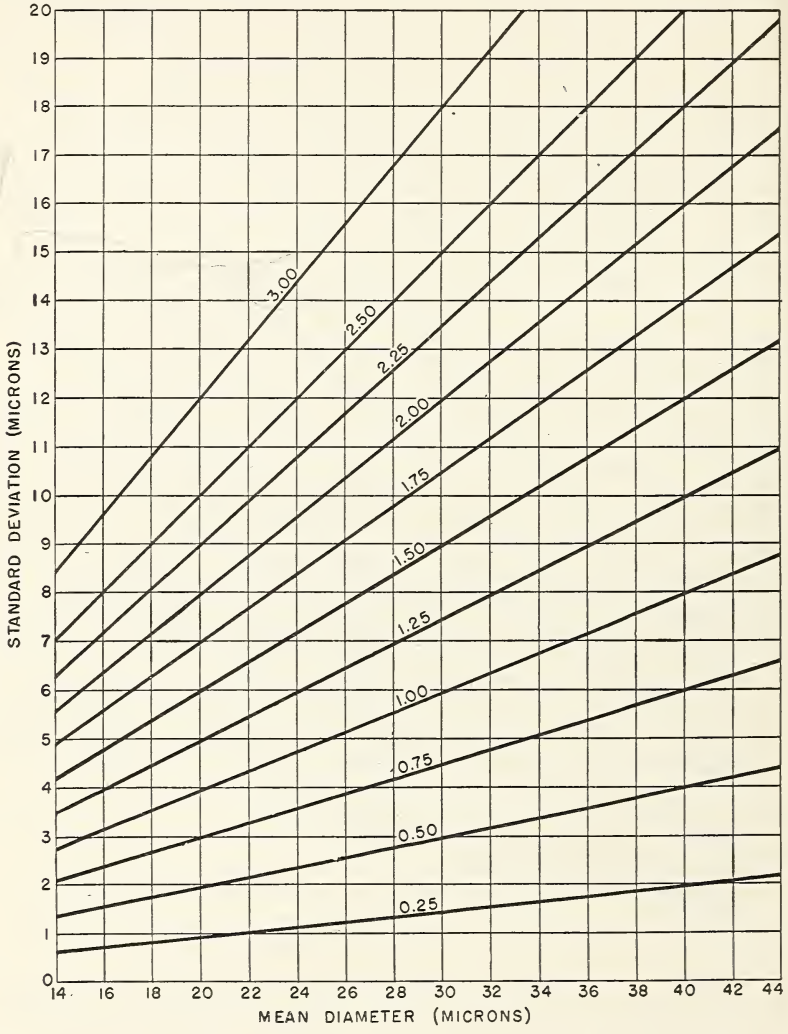

FIGURE 6.—Relationship between mean diameter and standard deviation for normal distribution of wool fibers. Locus of each curve depends on a given coefficient of dispersion $\left(\frac{\text{range}}{\text{mean diameter}}\right)$ for 100 fibers. Numbers on curves represent coefficients of dispersion.

obtained by dividing the standard deviation by the mean diameter. Mathematically, the coefficient of variation corresponds to the slope of the given set of curves; the greater the slope or incline the greater the variation.

TABLE 2.—*Comparison of standard deviations for variability of wool fibers, determined by different methods*

Sample No.	Standard deviation			Sample No.	Standard deviation			Sample No.	Standard deviation		
	Calculated	Estimated by use of—			Calculated	Estimated by use of—			Calculated	Estimated by use of—	
		Tippett's formula (fig. 6)	Curves shown in fig. 5			Tippett's formula (fig. 6)	Curves shown in fig. 5			Tippett's formula (fig. 6)	Curves shown in fig. 5
	Microns	*Microns*	*Microns*		*Microns*	*Microns*	*Microns*		*Microns*	*Microns*	*Microns*
1	3.54	3.4	3.8	11	8.15	6.4	7.0	21	13.03	9.2	11.0
2	3.61	3.8	4.0	12	8.17	6.8	8.6	22	13.85	11.0	14.2
3	4.34	3.8	4.2	13	9.52	7.2	10.5	23	14.24	15.4	12.8
4	4.83	4.6	5.4	14	9.90	7.8	8.9	24	14.95	17.8	14.7
5	5.21	4.8	5.3	15	10.02	8.8	10.0	25	15.81	17.6	15.8
6	5.93	4.2	4.7	16	10.39	9.0	9.5	26	15.81	18.0	15.9
7	6.07	5.6	6.5	17	11.36	9.3	10.7	27	16.09	15.6	15.4
8	6.47	4.8	5.6	18	11.74	7.4	12.5	28	16.12	14.6	14.2
9	7.16	7.2	8.0	19	12.40	15.2	12.9				
10	7.21	6.6	8.1	20	12.45	14.0	12.5				

COMPARATOR METHOD

Because of its practicability, the method of judging the fineness of wool merely by looking at it has been widely used by wool growers, buyers, and mill operators. However, there are serious objections to this method when precise measurements are required. The human eye unaided cannot accurately estimate the variation in size of fibers in a given sample of wool. As a substitute for this method, a rapid comparison method, in which unknown samples are compared with standard known samples, was developed for estimating fineness and variability of wool. For descriptive purposes, this is called the comparator method.

During the first stages of the work with the microprojector, while pictures of the cross sections on sensitized paper were being obtained, it was noticed that the operator was inclined to judge the fineness and variability of a given sample. Only standards for making the comparison seemingly were lacking. These standards had to be so selected as to conform to accepted United States standards for grading wool and also had to be flexible enough to indicate the types of distribution of fibers that may occur in a given grade of wool. As a basis for determining the grade of wool, Von Bergen's measurements (*8*) for average diameter of wool tops were used to make a quality key. This quality key furnishes the average diameter range for the various grades, as shown in table 3. In order to have the standard grades spaced in definite steps, the standards for various grades should have definite average diameters. This average diameter was selected to lie on the lower limit of the range for each grade in order that the range for each grade might be shown.

Comparison of wool samples for fineness is complicated by the fact that in samples with the same average diameter there are various distributions of small and large fibers. These distributions are quantitatively expressed in terms of standard deviation or coefficient of variation. Since a great variety of variations in mean diameter is possible, types of variability have been grouped for convenience under

three classes. These three classes have been called choice, average, and poor in uniformity, corresponding respectively to a very uniform distribution of evenly sized wool fibers, a distribution of moderately uniform wool, and, finally, a distribution consisting of very fine and very coarse fibers. They are designated mathematically by three ranges in coefficient of variation: Choice, 10–15 percent; average, 15–18 percent; and poor, 18–30 percent. For each United States numerical grade, samples were selected from the three classes of variability. From these samples it was found that the average values for the coefficients of variation of the three classes are as follows: Choice, 13 percent; average, 17 percent; and poor, 22 percent.

TABLE 3.—*Range of average fiber diameter for wool tops and average diameter for the standard samples used on the comparator*

United States grade [1]	Diameter of wool fibers		United States grade [1]	Diameter of wool fibers		United States grade [1]	Diameter of wool fibers	
	Range of average [2]	Average		Range of average	Average		Range of average [2]	Average
	Microns	*Microns*		*Microns*	*Microns*		*Microns*	*Microns*
80's	19. 50	18. 66	56's	24. 81–26. 90	26. 71	44's	34. 81–36. 60	36. 25
70's	19. 51–20. 80	20. 56	52's		28. 41	40's	36. 61–38. 30	37. 68
64's	20. 81–21. 90	21. 61	50's	26. 91–30. 40	29. 54	36's	38. 31–39. 30	39. 50
60's	21. 91–23. 50	22. 36	48's	30. 41–33. 00	31. 06			
58's	23. 51–24. 80	24. 70	46's	33. 01–34. 80	33. 34			

[1] Each grade is represented by three different coefficients of variation: Choice, 13 percent; average, 17 percent; and poor, 22 percent.

[2] The values here shown were accepted by investigators as the ranges in fineness for the corresponding United States grades at the time (1937) when the experimental work was conducted. Since that time certain changes have been made in the values.

The fact that wools on the average are neither extremely uniform nor extremely variable makes it difficult to select standard cross sections to represent the choice and poor classes of variability. This accounts for the somewhat higher value, than the medium, for the coefficient of variation in the choice class and the lower value in the poor class than might be expected.

There are a number of ways by which the standard samples may be brought into comparison with the unknown sample. The first method employed was unusual. A device resembling a squirrel cage (fig. 7) was used. The photomicrographs were mounted on rectangular surfaces forming three parallelepipeds with a septagonal cross section which were arranged end to end and pivoted through their axes so that photomicrographs of the cross sections might be moved and held at any position for comparison with projections of the cross sections. The projection was made on a ledge rigidly fastened adjacent and parallel to the standards on the "squirrel cage."

An improved method [2] of mounting the cross sections made use of an endless belt or tape. The unknown sample was projected beside this tape containing the standards. The standards were illuminated from the rear by a simple lighting arrangement.

In order to expedite further the method for obtaining a record of the wool samples, another technique has been devised. In this method the cross sections are made in the usual way but are recorded on a film strip (35 millimeter) through the use of a small camera adapted to an ordinary microscope. Identity of the sample may be written on the film strip or, preferably, recorded photographically. The latter

[2] Developed and reported in 1937 by J. O. Grandstaff, Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, N. Mex.

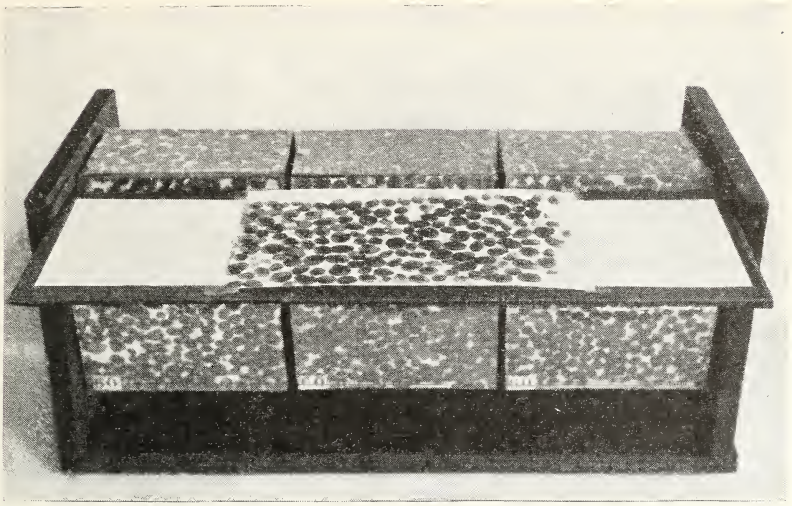

FIGURE 7.—An apparatus known as a comparator for judging fineness of a cross section of wool magnified 500 diameters.

method decreases the chances of error. In a similar manner standard samples are recorded on a film strip. This recording can be done by taking exposures of standard samples through a microscope or by taking pictures of photomicrographs of the various standards. Comparison of the known cross sections with the unknown is now greatly facilitated, as cross sections of wool fibers of known and unknown values may be projected at the same magnification by means of two film-strip projectors (fig. 8). This method is exceedingly rapid, less costly, and furnishes a permanent record of any given sample.

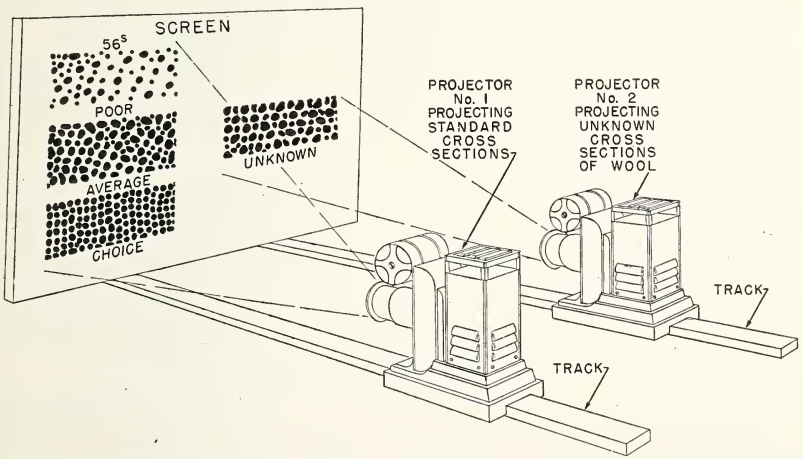

FIGURE 8.—Two film-strip projectors arranged parallel, showing cross sections of wool fibers at 1,000 diameters' magnification. The standard appears on the left and the unknowns on the right. Both projectors are mounted on adjustable bases which facilitate adjustment of the projections to the proper magnification. This magnification must be the same for standard and unknown wool cross sections.

The degree of accuracy possible with this method is shown in tables 4 and 5. In these a comparison is made of values of mean diameter obtained by calculation, by the count method, and by the comparator method.

Variations in the comparator method are possible, depending on the equipment available in the laboratory and the need for speed in getting the data tabulated.

TABLE 4.—*Comparison of calculated and estimated mean diameters for samples of 100 fibers*

Sample No.	Mean diameter obtained by—			Sample No.	Mean diameter obtained by—			Sample No.	Mean diameter obtained by—		
	Calculation	Estimation by—			Calculation	Estimation by—			Calculation	Estimation by—	
		Count method	Comparator method			Count method	Comparator method			Count method	Comparator method
	Microns	*Microns*	*Microns*		*Microns*	*Microns*	*Microns*		*Microns*	*Microns*	*Microns*
1	17.8	18.0	18.6	8	24.9	25.5	21.6	15	36.6	36.3	37.7
2	20.7	20.2	20.8	9	28.1	28.5	21.6	16	36.7	35.0	36.1
3	20.7	20.5	21.6	10	28.5	28.2	28.4	17	36.9	36.0	29.5
4	21.0	20.6	18.7	11	29.3	28.0	28.4	18	36.9	36.0	37.7
5	22.2	21.3	22.3	12	30.9	29.7	27.5	19	37.0	36.2	37.7
6	23.0	22.6	24.7	13	35.1	34.2	36.1	20	39.6	39.0	39.3
7	24.3	23.8	26.7	14	36.6	35.6	39.3				

TABLE 5.—*Comparison of the variability in samples of wool fibers, as determined by calculation and use of the comparator*

Sample No.	Calculated coefficient of variation [1]	Coefficient of variation obtained by comparator [1]	Sample No.	Calculated coefficient of variation [1]	Coefficient of variation obtained by comparator [1]	Sample No.	Calculated coefficient of variation [1]	Coefficient of variation obtained by comparator [1]	Sample No.	Calculated coefficient of variation [1]	Coefficient of variation obtained by comparator [1]
	Percent	*Percent*		*Percent*	*Percent*		*Percent*	*Percent*		*Percent*	*Percent*
1	10.5	13	8	14.3	13	14	15.5	22	20	17.6	17
2	11.2	17	9	14.3	22	15	16.1	13	21	18.0	17
3	12.4	13	10	15.1	13	16	16.3	17	22	18.2	17
4	12.7	13	11	15.1	17	17	16.6	17	23	32.4	over 22
5	13.0	13	12	15.2	13	18	17.2	17	24	34.3	over 22
6	13.0	13	13	15.4	13	19	17.3	13	25	36.5	over 22
7	13.6	13									

[1] Choice, 13 percent; average, 17 percent; and poor, 22 percent.

Direct projection and immediate measurement of the image of the cross section are possible through a microprojector designed for that purpose or by means of an ordinary microscope which has been supplied with a more intense source of light. The various systems of comparison may be used in conjunction with such a set-up with good results. However, records on sensitized paper and film strips are often necessary for filing purposes and for more detailed study, and therefore the photographic methods of comparison are favored.

Combination of the count method and comparator method is possible and utilization of combined features of both can be made. In this laboratory the unknown is first analyzed by the count method to give the mean diameter. The comparator method is then used to give the variability existing in the wool sample. This procedure eliminates computation entirely and makes comparison easier, since it is necessary to know only one variable, the degree of uniformity of the fibers.

SUMMARY

Two methods are presented for quickly analyzing cross sections of wool fibers as a means of determining the fineness and variability of a sample of wool.

It has been pointed out that although the technique for cross-sectioning and projecting the cross sections at the desired magnification has been greatly improved in the last few years, methods for calculating the fineness and variability have still depended on individual measurement of at least 100 wool-fiber cross sections.

By a count method whereby the number of wool-fiber cross sections are counted in a given area, the average diameter of wool samples can be estimated within ± 0.5 micron of the value obtained by an individual measuring of 100 cross sections of fibers.

The comparator method is an improvement over the older methods of eye judgment of wool fineness and therefore is applicable for grading wool. By the comparator method, selecting and culling a flock of sheep on the basis of the merit of the fleece are accomplished with greater precision and accuracy. When rapidity is uppermost, this method is superior to the count method.

Curves are furnished that make estimation of fineness and variability possible. The curves show greater variability in diameters of wool fibers of the coarser grades. Conversely, fine wools usually are more uniform.

The application of these methods for analyzing the cross sections of wool fibers is believed to make the cross-section method superior to other methods for determining fiber fineness and variability. These methods are not limited in their scope to wool but can be applied to other textile fibers and to other systems of grading.

Furthermore, the cross-section method furnishes a permanent record in the form of a photostat on paper or photomicrograph on film.

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